ENERGY ENGINEERING ANALYSIS PROGRAM (EEAP)

I of IV

BOILER/CHILLER PLANT STUDY
FORT HOOD, TEXAS

FINAL SUBMITTAL

EXECUTIVE SUMMARY

U.S. ARMY CORPS OF ENGINEERS

OCTOBER 1991

ROMINE, ROMINE & BURGESS, INC.
MECHANICAL & ELECTRICAL
CONSULTING ENGINEERS
FORT WORTH TEXAS

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FINAL SUBMITTAL

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INTRODUCTION

The Fort Hood Boiler/Chiller Plant Study conducted by Romine, Romine & Burgess, Inc., Consulting Engineers under Contract DACA63-88-C-0078 has permitted a unique level of A/E insight into the many faceted picture of plant operations at a major military installation. As implied by the title of this project, its scope has been limited strictly to the primary components of heating and cooling generating equipment in such plants, along with only those associated accessories directly involved therewith and in the immediate vicinity.

The study has also devoted considerable time to consideration of maintenance and operating procedures of these plants in the execution of their appointed missions, leading to several broad and generalized conclusions:

1. Essentially all operation and maintenance of equipment involved in this study is provided by civilian employees of the Directorate of Engineering & Housing. Similarly, as opposed to the typical non-military building of like size and function, literally <u>no</u> operating or maintenance activities at any of the plants are provided by occupants of those buildings. The net result is that only at Base Hospital 36000 is there a full-time resident staff dedicated to maintaining the continuity of equipment operation and effectiveness of life support services.

   For all other plants the procedure in force is that the heating department handles boilers and the cooling department handles chillers and refrigeration systems, with technician specialists each being assigned a group of buildings as his primary responsibility under the overall direction of a supervisor. As a low-visibility strictly "overhead" type of operating expense, competing for annual budget funds with all other departments including those having a much more direct and obvious role in the military mission of this installation, the inevitable cutbacks and reductions in force have occasioned the stretching of manpower resources to the point that preventative maintenance can take place for the most part only in the off-season. At all other times nothing much more than "breakdown maintenance" can be provided.

2. In common with operating and maintenance personnel everywhere, the first priority <u>has</u> to be effective response to complaints, with long-range operating life of equipment components a very secondary consideration, and with efficient operation from an energy consumption standpoint a distant third. The inevitable consequence of this default situation is the early disconnection of any kind of energy conservation control or procedure which (1) results in

enough occupant discomfort to occasion service calls or (2) requires any degree of operator attention or on-site "tuning" to be effective. With neither the time, the opportunity, nor any direct motivation to make the equipment last longer or operate more efficiently, the unavoidable result is premature equipment failure and an excessive replacement rate, coupled with very high operating costs but with little or no accountability due to the lack of individual energy metering at each building or any effort at comprehensive trending or comparing of individual utility costs on a building-by-building basis.

3. A third significant element which works against all installations operated by the Federal Government, and obviously that least likely of being improved in the foreseeable future, is that of the "lowest common denominator" effect in the quality of installed equipment components, brought on by government procurement regulations in the effort to "give everybody an equal chance". Exacerbated by the usual 3 to 5 year (or longer) delay between the state-of-the-art and government guide specifications, plus an almost total lack of involvement of the original designers of mechanical systems in the construction or commissioning process of any A/E designed building, this system results in what frequently is a rather poor implementation of the original design concept.

All these factors add an unnecessary burden on the operating staff, whose primary responsibility is to see that an adequate amount of heating or cooling is generated by <u>whatever</u> is installed, with little or no specific instruction as to any unique requirements or features, and with no questions asked so long as the necessary heating or cooling output is forthcoming.

Very few civilians, inside or outside the government, ever have the opportunity of knowing anything about the frequency with which major heating and cooling equipment is replaced on a military installation like Fort Hood. Knowledge gained in this regard from this study is rather shocking when compared to the norm for civilian structures, and indicative of the true cost of the various problems above noted. Many of the buildings in this study for example were constructed during the 1970's, yet in a number of instances it has already been necessary to replace boilers once or even <u>twice</u>, and with yet another cycle coming up for some.

As a general comparison, the A/E has been involved over the years with the Fort Worth Independent School District in a number of projects affecting all 104 school buildings. Like all operators of major complexes FWISD has periodically experienced equipment failures and unplanned replacements, but it is not at all unusual to go into a building built before 1920 and to find one or two of the original low pressure steam boilers, usually high firebox steel design, <u>still</u> in service after having operated each heating

season for over 70 years! Engineers did not begin using cast iron boilers in these buildings until around the early 30's in general, but many of these too remain in annual use. There are virtually no buildings constructed since 1970 that do not continue to use the originally installed equipment for both heating and cooling, except for a few chillers destroyed by vandalism or equipment replaced as a consequence of building expansion.

The main difference is the quality of equipment; "Kewanee", "Pacific", and "Superior" products predominating in the steel boilers, "Weil-McLain" and "Peerless" in cast iron boilers, and "Carrier" or "Trane" generally representing cooling equipment. This has resulted primarily from the greater freedom of control and selectivity permitted engineers in the private sector, plus their continuity with the project through construction and during the warranty period.

The other reason is the method of operation and maintenance, which is quite similar to that in place at Fort Hood in the way of a central maintenance department with heating and cooling sub-departments, responding to service call complaints as received, but with constantly roving preventative maintenance crews in specially equipped vans. The main difference is that each building is operated by an on-site individual, usually the school custodian. Certainly these "operators" are relatively very unskilled in that function, but at least can be taught the rudiments of starting and stopping components and are in the building at all times, having frequent opportunity to observe that something abnormal may be developing, and definitely alert to call for appropriate help as soon as anything beyond their range of abilities begins to show up.

As good tax-paying citizens of the United States of America, the staff members of Romine, Romine & Burgess, Inc. are entitled to an opinion as to how the Army might improve maintenance and operating procedures at Fort Hood, and one of the goals of this overall study is to make certain suggestions along those lines. It would however be rather unrealistic to assume implementation of significant changes in staff size or fundamental procedures, as such decisions are influenced much more greatly by a wide variety of additional considerations. Predicating then that operation and maintenance can be expected to continue indefinitely along pretty much the same format as at present, the kinds of Energy Conservation Opportunities (ECO's) which could be expected to have any long-range impact have to be rather fundamental in nature, productive without requiring any particular degree of operator "tuning", and likely to remain effective under extended periods of unattended operation.

It is this basic philosophy that has guided the consideration of alternatives for ECO's at the assigned buildings, with two basic departures. The first has to do with the cardinal energy conservation measure which can be taken on any building subject

to day-time occupancy only -- the simple act of not running heating or cooling equipment when there is no one there to benefit from it. Even though the majority of buildings in this study were at one time provided with operating controls for schedule optimizing and which controls have been deactivated as an operating expedient, the potential return on investment is simply too great to be ignored. It is to be hoped that deactivation of this type energy conservation control system was essentially an over-reaction against some other deficiency which contributed to the situation that was unsatisfactory, and that the more fundamental and simplistic approach recommended by this study will be sufficiently useful and understood to be left in place.

The other major exception concerns several buildings reported by the operators to be short of cooling capacity. These conditions were confirmed by cooling load analyses performed under this study, and as compared against the rated output of the installed equipment. In such cases the study does recommend replacement of the chilling equipment with sufficiently large new equipment and associated auxiliaries, assuming the use of high efficiency components and under as many alternatives as can apply under the circumstances, but does not go through the meaningless exercise of "evaluating" an array of ECO's for the present equipment is already known to be undersized and inadequate to the task.

ROMINE, ROMINE & BURGESS, INC.

Thos B. Romine Jr.
10/31/91

Thos. B. Romine Jr., P.E.
FASHRAE, FAPEC, FACEC

SECTION 1
EXECUTIVE SUMMARY

The scope of this project consists of: (1) survey and testing of thirty-eight (38) boiler/chiller plants and their operation; (2) determination if efficiency can be improved by: repair, addition, modification of equipment, control systems, and operation and maintenance practices; (3) identification of all Energy Conservation Opportunities (ECO's); (4) preparation of program documentation (Form DD 1391's, project development brochures, etc.) for certain ECO's; and (5) preparation of a comprehensive report of all findings.

After a physical inspection of all plants, the A/E determined that some plant equipment was in need of complete replacement and/or was in need of repair for safety reasons, but no feasible opportunities existed to improve efficiency by repairing plant equipment. Also, due to the lack of sufficient operation and maintenance personnel (as discussed in the Introduction), O&M practices to increase plant efficiency were not considered in this study.

Since no data on electrical or gas metering of individual buildings or boiler plant log data for quantities of steam productions were available for this study, the A/E was responsible for estimating all energy consumed by each plant.

Considering energy conservation opportunities for a series of boiler and/or chiller plants at a military base is rather different from that type analysis as it is usually approached for a conventional building. The difference is that of emphasis, in that only the primary heating and cooling equipment in such facilities is involved and subject to optimizing modifications or enhancements, while the buildings served by such plants are completely ignored in that context.

At the same time it is precisely those same buildings which drive the analysis of the heating and cooling plants, as generators of the heating and cooling loads imposed. As such the supported buildings must be subjected to the same kind of annual heating and cooling energy use analysis as though the buildings were themselves subject to ECO considerations. For the purposes of this analysis it was therefore necessary to simulate the annual energy performance of each building or group of buildings served by each of the boiler or chiller plants involved, using the Carrier H.A.P. (Hourly Analysis Program) computer program for that purpose.

The original concept developed by the A/E for execution of work under this contract was to concentrate initial efforts on the acquisition of as-built drawings for the buildings in question, first the plants themselves and then the buildings supported by

such plants. This goal was oriented to the acquisition of basic information at the earliest possible date, not only to have on hand when needed but to benefit from the familiarization of staff members with the buildings and equipment components that would be involved in the course of the study. It was also planned to mount an almost parallel effort in physically surveying these buildings, the plants in detail and the supported buildings somewhat superficially, but with the benefit of as-built information for pre-visit orientation. As discussed in Section 2, "Acquisition of Data" unforeseen circumstances forced a change in direction and greatly delayed the obtaining of as-built data. It was determined to press on with the survey effort regardless however, and the bulk of this work was completed during the months of August and September, 1988, at least with regard to the energy plants proper. Survey activities and walk-through inspections of the supported buildings by and large occurred later at various times during the progress of this project.

Testing of the chillers was hoped to be accomplished during August and September of 1988, but for various reasons was delayed in beginning until the last week of September of that year. Chiller testing continued into October, 1988 and each chiller was tested at least once and occasionally twice for confirming earlier results that suggested a question of one type or another.

Analysis of this round of chiller testing began immediately, but with a number of inconsistencies beginning to show up for which there was no ready explanation. Analysis of the test data and the experience of having been through each of the affected plants in some detail soon led to the conclusion that a more sophisticated model of ultrasonic flow-measuring device would be required to verify test results recorded for a significant number of plants during the next cooling season.

Testing of boilers then became the next level of priority, and this activity began in mid-January, 1989. Each boiler assigned to this study was tested with a microprocessor-based electronic test instrument known as a flue-gas analyzer in accordance with Section 3 of the ASME Power Test Code 4.1, as discussed in some detail in Appendix B(5). Results of boiler tests were also questioned in certain areas subsequent to appropriate analysis, and a significant number of boilers were retested during March, 1989 for verification purposes.

The retesting of chillers began as soon as sustained periods of hot weather could be expected, July of 1989, and was completed during that month.

The problems associated with acquisition of as-built data for buildings continued through most of 1989, with analysis of test results and evaluation of building operation considering the effect of potential ECO's continued in a parallel manner as data availability permitted.

Finally having all as-built information on hand, the opportunity was available in late 1989 to complete all analysis efforts and collate the results for purposes of this report. Processing the multitude of data involved required the use of more than 15 megabytes of computer storage for maintenance of the various files and special spreadsheet templates for appropriate manipulation. Results of this overall effort are described and tabulated as appropriate elsewhere in this report.

Fifteen (15) copies of the Interim Submittal were sent to the appropriate government personnel in April, 1990. A/E received three (3) sets of comments for the Interim Submittal from Mr. Paul Cox of U.S. Army Engineer District, Fort Worth on 18 June 1990. The comments originated from the following offices: CESAM-EN-CC, CEHSC-FU-M and CESWD-ED-MM. A/E was promised additional comments, including some from Fort Hood.

A/E contacted Mr. Paul Cox during the following months on several occasions with regard to additional comments, but was informed that no more had been received. In an attempt to "jump-start" this project, A/E sent a transmittal to Mr. Paul Cox on 29 October 1990 with responses to initial comments and a request that a date be set for the Interim Submittal Meeting.

On 20 February 1991, A/E received a phone call from Mr. Richard Champagne stating that Mr. Paul Cox had retired and that he (Champagne) was now the Project Manager for this study. Mr. Champagne informed the A/E that the Interim Submittal Meeting would be on 17 April 1991. At the meeting, initial Interim Submittal comments were discussed and Fort Hood personnel explained that they were now emerging from the turmoil of Desert Shield and Desert Storm and could transfer some of their efforts again to this study.

Approximately one (1) month following the Meeting, A/E received Interim Submittal comments from Fort Hood and responded to them immediately. A two-part review meeting occurred at the Fort Worth District Office of the Corps of Engineers on 11 and 12 June 1991 to: (1) review A/E ECO recommendations; (2) review A/E responses to Fort Hood comments, and (3) decide upon a final direction for this study.

ECO recommendations were presented to Mr. Champagne in the form of ECIP's, QRIP's, OSD PIF's, and PECIP's at the review meeting. The ECIP requirement that a project cost more than $200,000 and have a simple payback less than 4 years, as set forth in the 15 June 1989 memorandum "Energy Conservation Investment Program (ECIP) Guidance" issued by the Director of the U.S. Army Engineering and Housing Support Center, had limited the number of potential ECIP packages. Mr. Champagne informed the A/E that the current ECIP criteria had been modified to incorporate any projects with a simple payback of less than 8 years. A phone call was placed to Fort Hood and Fort Hood personnel stated that all A/E responses to their comments were acceptable. Finally,

all parties reached agreement as to the final direction of this study and the appropriate new projects have been developed and accompany this submittal.

Existing cooling plant loads and chiller types, capacities, and tested efficiencies can be found in Table 1-1. "As-Built Cooling Load" was derived from chiller equipment schedules on as-built drawings received from Fort Hood (if the drawings were available) and "Calculated Cooling Load" was calculated using the "Carrier" H.A.P. computer program. Efficiencies represent kW/ton at full load.

Existing heating plant loads and boiler types, capacities, and tested efficiencies can be found in Table 1-2. All boilers are forced-draft, low pressure type, unless otherwise noted. Heating loads represent heating, domestic hot water, and kitchen steam demands. "As-Built Heating Load" was derived from boiler equipment schedules on as-built drawings received from Fort Hood (if drawings were available) and "Calculated Heating Load" was calculated using the "Carrier" H.A.P. computer program and water heating spreadsheets. Efficiencies represent overall fuel-to-steam or fuel-to-hot water percentages at full load.

Present annual energy consumption rates by cooling plants are shown in Table 1-3. Chiller energy was calculated by the "Carrier" H.A.P. program and chilled water pump, condenser water pump, and cooling tower fan energy was calculated by auxiliary equipment spreadsheets. Cooling plants incorporated within this study consume 126,642 MBTU of electrical energy annually.

Present annual energy consumption rates by heating plants are shown in Table 1-4. Building heating energy was calculated by the "Carrier" H.A.P. program and heating water pump, boiler burner fan, condensate return pump, water heating and kitchen steam energy was calculated by auxiliary equipment spreadsheets. Heating plants incorporated within this study consume 4,991 MBTU of electrical energy and 319,251 MBTU of natural gas energy annually.

No historical energy consumption was available from Fort Hood.

The following cooling Energy Conservation Opportunities (ECO's) were investigated:

C-1 Install time-switch to control chillers, chilled water pumps, condenser water pumps, and cooling towers.

C-2 Reset chilled water temperature leaving chiller.

C-3 Cycle cooling tower fans.

C-4 Install "turbo-modulator" to vary chiller compressor speed.

C-5 Install high-efficiency motors on chilled water pumps, condenser water pumps, and cooling tower fans.

C-6 Replace chilled water pumps.

C-7 Replace condenser water pumps.

C-8 Replace cooling towers.

C-9 Replace chillers.

All logical combinations of the previous nine ECO's were also studied.

The following <u>heating</u> ECO's were investigated:

B-1 Install time-switch to control boilers, heating water pumps, and condensate return pumps.

B-2 Install efficient forced-draft water heaters to serve domestic water heating demands year-round.

B-3 Install water heaters to serve water heating demands during the summer season.

B-4 Install atmospheric low pressure kitchen boilers to serve kitchen steam demands year-round.

B-5 Install kitchen boilers to serve kitchen steam demands during the summer season.

B-6 Install high-efficiency motors on heating water pumps.

B-7 Replace boilers to serve building heating, water heating, and kitchen steam demands.

B-7H Install boilers to serve building heating demands.

B-7W Install boilers to serve building heating and water heating demands.

B-7K Install boilers to serve building heating and kitchen steam demands.

B-8 Install auxiliary heat recovery condenser on chiller to pre-heat domestic hot water.

All logical combinations of the previous eleven ECO's were also studied.

The following ECO's are recommended based upon highest potential energy savings and criteria set forth by ECIP and PECIP programs:

Plant	ECO's
121	C-1, C-2, C-6, C-7, C-9
135	C-1, C-2, C-5, C-9
2805	C-1, C-2, C-6, C-7, C-9
5764	C-1, C-2, C-5, C-9
5792	C-5
7051	C-5
23001	B-1, B-2, B-4, B-6, B-7H
27004	C-2, C-5, C-9, B-2, B-4, B-6, B-7H
29005	C-2, C-5, C-9
31008	C-2, C-5, C-9, B-2, B-4, B-6, B-7H
34008	C-2, C-5, C-9, B-2, B-4, B-6, B-7H
36000	C-9, B-8N
36009	B-7W
36014	C-5
37005	B-1, B-2, B-4, B-7H
37007	B-1, B-2, B-4, B-7H
39015	C-5
39043	C-2, C-6, C-9, B-6, B-7W
41003	C-5, B-2, B-6, B-7H
41007	B-1, B-2, B-4, B-7H
42000	C-1, C-2, C-5, C-9
50001	C-1, C-2, C-5, C-9
50004	C-1, C-5
87018	C-2, C-5, C-9
90038	B-1, B-2, B-4, B-7H
91001	C-5, B-2, B-6, B-7K

All other investigated ECO's were rejected because they either did not meet ECIP, QRIP, OSD PIF, and PECIP criteria; or in certain cases a plant has been overcome by events, programmed for a future project, chiller already replaced, etc. Reasons for additional ECO's which were not investigated can be found in Section 11.

The following three (3) ECIP Projects were developed:

1. Replace two (2) chillers and install one (1) heat recovery condenser at Plant 36000.

Plant	ECO's	SPB (Years)
36000	C-9 + B-8N	4.81

Life Cycle Cost Analysis Summary:

Total Investment Cost	Annual Electric Savings MBTU	Annual Gas Savings MBTU	Annual Dollar Savings	SIR
$308,332	2084	9151	$64,039	3.08

MBTU -- Million BTU's

Analysis Date: 2 August 1991
Programmed Year: FY 1992
Programmed Year Cost: $308,332

2. Replace boilers and install new heating equipment at twelve (12) plants.

Plant	ECO's	SPB (Years)
23001	B-1 + B-2 + B-4 + B-6 + B-7H	5.36
27004	B-2 + B-4 + B-6 + B-7H	7.05
31008	B-2 + B-4 + B-6 + B-7H	9.31
34008	B-2 + B-4 + B-6 + B-7H	7.83
36009	B-7W	8.43
37005	B-1 + B-2 + B-4 + B-7H	10.66
37007	B-1 + B-2 + B-4 + B-7H	7.38
39043	B-6 + B-7W	10.53
41003	B-2 + B-6 + B-7H	5.88
41007	B-1 + B-2 + B-4 + B-7H	10.15
90038	B-1 + B-2 + B-4 + B-7H	5.79
91001	B-2 + B-6 + B-7K	11.81

Life Cycle Cost Analysis Summary:

Total Investment Cost	Annual Electric Savings MBTU	Annual Gas Savings MBTU	Annual Dollar Savings	SIR
$987,014	1060	28146	$124,424	2.12

MBTU -- Million BTU's

Analysis Date: 2 August 1991
Programmed Year: FY 1992
Programmed Year Cost: $987,014

3. Replace chillers and auxiliary equipment at twelve (12) plants.

Plant	ECO's	SPB (Years)
121	C-1 + C-2 + C-6 + C-7 + C-9	6.29
135	C-1 + C-2 + C-5 + C-9	9.20
2805	C-1 + C-2 + C-6 + C-7 + C-9	8.68
5764	C-1 + C-2 + C-5 + C-9	8.79
27004	C-2 + C-5 + C-9	7.54
29005	C-2 + C-5 + C-9	9.90
31008	C-2 + C-5 + C-9	6.67
34008	C-2 + C-5 + C-9	7.72
39043	C-2 + C-6 + C-9	7.96
42000	C-1 + C-2 + C-5 + C-9	5.85
50001	C-1 + C-2 + C-5 + C-9	7.17
87018	C-2 + C-5 + C-9	9.23

Life Cycle Cost Analysis Summary:

Total Investment Cost	Annual Electric Savings MBTU	Annual Gas Savings MBTU	Annual Dollar Savings	SIR
$1,887,721	17447	0	$236,581	1.42

MBTU -- Million BTU's

Analysis Date: 2 August 1991
Programmed Year: FY 1992
Programmed Year Cost: $1,887,721

The following PECIP projects were developed:

1. Install high-efficiency motors at six (6) plants.

Plant	ECO's	SPB (Years)
5792	C-5	2.94
7051	C-5	1.62
36014	C-5	2.84
39015	C-5	4.33
41003	C-5	2.53
91001	C-5	2.53

Life Cycle Cost Analysis Summary:

Total Investment Cost	Annual Electric Savings MBTU	Annual Gas Savings MBTU	Annual Dollar Savings	SIR
$37,799	817	0	$11,079	3.33

MBTU -- Million BTU's

Analysis Date: 29 July 1991
Programmed Year: FY 1992
Programmed Year Cost: $37,799

2. Install time-switch and high-efficiency motors at Plant 50004.

Plant	ECO's	SPB (Years)
50004	C-1 + C-5	3.77

Life Cycle Cost Analysis Summary:

Total Investment Cost	Annual Electric Savings MBTU	Annual Gas Savings MBTU	Annual Dollar Savings	SIR
$10,364	203	0	$2,753	3.02

MBTU -- Million BTU's

Analysis Date: 18 July 1991
Programmed Year: FY 1992
Programmed Year Cost: $10,364

The annual energy and cost savings of the three ECIP projects and two (2) PECIP projects are summarized in Table 1-5. If all projects were implemented, Fort Hood could save 21,611 MBTU in electrical energy and 37,297 MBTU in gas energy annually, resulting in a total annual cost savings of $438,877.

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TABLE 1-1

CHILLER DATA

Cooling Plant	Chiller Type	As-Built Cooling Load Tons	Calc. Cooling Load Tons	Existing Chiller #1--> Cap. Tons	Eff. KW/Ton	Existing Chiller #2--> Cap. Tons	Eff. KW/Ton	Existing Chiller #3--> Cap. Tons	Eff. KW/Ton	Total Plant-> Cap. Tons	Avg. Eff. KW/Ton
121	W.C. Centf.	199	138	193	1.01	-	-	-	-	193	1.01
135	W.C. Recip.	72	52	72	1.47	-	-	-	-	72	1.47
194	W.C. Centf.	230	107	228	1.03	-	-	-	-	228	1.03
410	W.C. Centf.	220	238	110	.83	110	.90	-	-	220	.87
2805	W.C. Centf.	N.A.	116	151	1.06	-	-	-	-	151	1.06
5764	W.C. Centf.	178	143	178	.94	-	-	-	-	178	.94
5792	W.C. Centf.	171	176	181	.93	-	-	-	-	181	.93
7050	W.C. Centf.	416	306	191	1.32	191	1.39	-	-	382	1.36
7051	W.C. Centf.	170	168	150	.77	150	.85	-	-	300	.81
9418	W.C. Centf.	1000	1066	570	.99	511	.98	-	-	1081	.99
10006	W.C. Centf.	1072	1076	574	.99	490	.90	-	-	1064	.95
14020	W.C. Centf.	141	154	161	.94	-	-	-	-	161	.94
14023	W.C. Centf.	146	166	161	.99	-	-	-	-	161	.99
21002	W.C. Centf.	217	240	215	1.18	-	-	-	-	215	1.18
27004	W.C. Centf.	465	486	465	.94	-	-	-	-	465	.94
28000	W.C. Centf.	220	238	110	.82	110	.81	-	-	220	.82
29005	W.C. Centf.	948	836	500	.79	437	1.16	-	-	937	.98
31008	W.C. Centf.	435	458	432	1.01	-	-	-	-	432	1.01
34008	W.C. Centf.	465	485	465	.94	-	-	-	-	465	.94
36000	W.C. Centf.	1232	1155	377	.99	400	.63	475	.93	1252	.85
36006	W.C. Centf.	275	259	275	.67	-	-	-	-	275	.67
36009	A.C. Recip.	96	110	102	1.99	-	-	-	-	102	1.99
36014	W.C. Recip.	107	96	98	1.18	-	-	-	-	98	1.18
39015	W.C. Centf.	1130	980	645	.87	583	.82	-	-	1228	.85
39043	W.C. Centf.	1120	1084	577	.95	615	.91	-	-	1192	.93
41003	W.C. Centf.	227	232	228	1.04	-	-	-	-	228	1.04
42000	W.C. Centf.	209	189	210	.96	-	-	-	-	209	.96
50001	* A.C. Recip.	130	129	136	1.84	-	-	-	-	136	1.84
50004	W.C. Centf.	N.A.	306	120	.93	120	.86	125	.89	365	.89
87018	W.C. Centf.	948	902	468	.92	418	1.06	-	-	886	.99
91001	A.C. Recip.	122	123	123	1.49	-	-	-	-	123	1.49
91002	A.C. Recip.	N.A.	99	96	1.51	-	-	-	-	96	1.51

Notes: W.C. Centf. - Water Cooled Centrifugal
W.C. Recip. - Water Cooled Reciprocating
A.C. Recip. - Air Cooled Reciprocating
N.A. - Not Available
* - Split-System with Remote Air-Cooled Condenser

TABLE 1-2

BOILER DATA

Heating Plant	Boiler Type	As-Built Heating Load KBTUH	Calc. Heating Load KBTUH	Existing Boiler #1----> Cap. KBTUH	Eff. %	Existing Boiler #2----> Cap. KBTUH	Eff. %	Existing Boiler #3----> Cap. KBTUH	Eff. %	Total Plant--> Cap. KBTUH	Avg. Eff. %
14020	Steam	2568	1649	2568	71.2					2568	71.2
21002	Steam	6502	5669	3770	72.5	3347	75.8 *			7117	74.2
23001	Steam	6652	4714	3770	76.5	3770	77.5			7540	77.0
27004	Steam	13914	11563	7746	76.5	7756	73.5			15502	75.0
29005	Steam	23432	18202	13390	81.3	13390	75.8 *			26780	78.6
31008	Steam	13700	10985	6849	79.2	6849	77.2			13698	78.2
34008	Steam	13914	11563	7746	77.5	7746	75.5			15492	76.5
36000 ***	Steam	21573	21261	7097	73.8	7097	73.8	7097	72.8	21291	73.5
36006	Steam	9030	4110	5537	75.8 *	4251	75.9			9788	75.9
36009	Hot Water	4422	2582	5055	75.8 *					5055	75.8
37005	Steam	4014	3885	2650	73.6	3347	76.9			5997	75.3
37007	Steam	4014	3079	3500	74.2	3500	73.2			7000	73.7
39015 **	Steam	26780	24943	13390	81.2	13390	82.2			26780	81.7
39043 **	Hot Water	26780	25632	13390	80.3	13390	78.3			26780	79.3
41003	Steam	7692	4781	3845	75.8 *	3845	75.8 *			7690	75.8
41007	Steam	4014	3410	3347	78.9	3347	77.9			6694	78.4
87018	Steam	23432	22132	13390	80.3	13390	81.3			26780	80.8
90038	Steam	7120	3197	7120	77.3					7120	77.3
91001	Steam	N.A.	3577	2678	75.6	2678	75.8 *			5356	75.7

Notes: KBTUH - Thousand BTU's/Hour
* - Boiler was inoperable. Efficiency based on boiler study conducted by the California Energy Commission.
** - Boilers contain combination gas & #2 oil burner.
*** - Boilers provide 100 psig steam and contain combination gas & #2 oil burner.
N.A. - Not Available

TABLE 1-3

PRESENT ANNUAL ENERGY CONSUMPTION

COOLING PLANTS

Cooling Plant	Chiller MBTU	Chilled Water Pump MBTU	Condenser Water Pump MBTU	Cooling Tower Fan MBTU	Total Electrical Cooling Energy MBTU
121	933	239	307	113	1592
135	331	77	77	75	560
194	924	365	141	109	1539
410	1288	260	242	187	1977
2805	849	255	255	82	1441
5764	1305	246	154	149	1854
5792	1037	266	266	263	1832
7050	3202	1377	557	167	5303
7051	2412	425	210	132	3179
9418	6093	1569	797	613	9072
10006	7027	1642	1264	854	10787
14020	1055	162	162	127	1506
14023	1149	158	158	124	1589
21002	2004	341	166	249	2760
27004	3380	1011	505	472	5368
28000	1214	260	242	187	1903
29005	4797	1881	585	539	7802
31008	3419	533	343	475	4770
34008	3375	531	505	475	4886
36000	8225	2155	1259	596	12235
36006	1038	985	266	206	2495
36009 *	1258	126	0	0	1384
36014	928	387	102	127	1544
39015	4984	1946	749	1363	9042
39043	5811	2426	968	775	9980
41003	1793	264	165	245	2467
42000	1984	267	267	243	2761
50001 *	1858	316	0	0	2174
50004	2138	242	308	198	2886
87018	5144	1881	610	563	8198
91001 *	951	126	0	0	1077
91002 *	573	106	0	0	679
				Annual Total	126642 MBTU

Notes: MBTU - Million BTU's
* - Air-Cooled Chiller; no condenser water pumps & cooling towers.

TABLE 1-4

PRESENT ANNUAL ENERGY CONSUMPTION

HEATING PLANTS

Heating Plant	Electrical Energy ---> Heating Water Pump MBTU	Boiler Burner Fan MBTU	Condensate Return Pump MBTU	Gas Energy ---> Building Heating MBTU	Water Heating MBTU	Kitchen Steam MBTU	Total Electrical Heating Energy MBTU	Total Gas Heating Energy MBTU
14020	24	33	4	1776	2036	0	61	3812
21002	78	128	7	4473	4677	2644	213	11794
23001	80	68	2	3701	1752	2397	150	7850
27004	177	185	4	9305	11897	3029	366	24231
29005	0 *	232	45	11407	14944	1820	277	28171
31008	177	185	7	8009	11243	2862	369	22114
34008	156	185	4	9120	11635	2962	345	23717
36000	0 *	158	101	18898	16794	10852	259	46544
36006	299	80	1	1881	4061	0	380	5942
36009	99	125	0 **	1178	2286	0	224	3464
37005	10	70	10	1737	2198	3140	90	7075
37007	10	70	3	1878	2502	1271	83	5651
39015	0 *	236	55	13802	18835	2183	291	34820
39043	604	375	0 **	12165	22173	0	979	34338
41003	54	126	2	4531	5522	0	182	10053
41007	10	70	9	1668	2277	2130	89	6075
87018	0 *	235	68	14013	16455	1708	303	32176
90038	5	157	3	1559	1735	2349	165	5643
91001	107	56	2	2634	2147	1000	165	5781
						Annual Totals	4991	319251 MBTU

Notes: MBTU - Million BTU's
* - Building heating served by steam coils or heating water pumps not in scope of work.
** - Hot water boilers, no condensate return pump.

TABLE 1-5

ANNUAL ENERGY AND COST SAVINGS

Project	Existing Electrical Usage MBTU	Existing Electrical Usage Costs	Existing Gas Usage MBTU	Existing Gas Usage Costs	After ECO's Implemented Electrical Usage MBTU	After ECO's Implemented Electrical Usage Costs	After ECO's Implemented Gas Usage MBTU	After ECO's Implemented Gas Usage Costs	Electrical Savings MBTU	Electrical Savings Costs	Gas Savings MBTU	Gas Savings Costs	Energy Conserved Elec. %	Energy Conserved Gas %
ECIP #1	12494	169419	46544	181987	10410	141160	37393	146207	2084	28259	9151	35780	16.68	19.66
ECIP #2	3207	43487	155992	609929	2147	29113	127846	499878	1060	14374	28146	110051	33.05	18.04
ECIP #3	51386	696794	0	0	33939	460213	0	0	17447	236581	0	0	33.95	0.00
PECIP #1	19141	259552	0	0	18324	248473	0	0	817	11079	0	0	4.27	0.00
PECIP #2	2886	39134	0	0	2683	36381	0	0	203	2753	0	0	7.03	0.00
								Totals	21611	293046	37297	145831		

Total Annual Cost Savings 438877 Dollars

ECIP #1 - Replace two (2) chillers & install one (1) heat recovery condenser at Plant 36000.
ECIP #2 - Replace boilers & install new heating equipment at twelve (12) plants.
ECIP #3 - Replace chillers & auxiliary cooling equipment at twelve (12) plants.
PECIP #1 - Install high-efficiency motors at six (6) plants.
PECIP #2 - Install time-switch & high-efficiency motors at Plant 50004.